THEMIS ROTO IMAGES: A UNIQUE OFF-AXIS DATASET FOR DETERMINING SURFACE ROUGHNESS CHARACTERISTICS. B. E. McKeeby[1] , M. S. Ramsey[1], and C. M. Simurda[1] . Department of Geology and Environmental Science, University of Pittsburgh, 4107 O'Hara Street SRCC, Pittsburgh, PA, 15260 (bem101@pitt.edu)

Introduction: The ability to assess the roughness of a planetary surface is limited by the spatial resolution of the instrument data used. Roughness can be described as the topographic expression of the surface caused by its rock abundance. This variation in surface characteristics commonly occurs at spatial scales smaller than those available from orbital instrumentation [1]. Understanding the surface at the sub-pixel scale is important for examining a number of processes such as dust deposition and mantling, volcanic flow properties, and the rock abundance [1-3]. Techniques have been developed to derive such surface characteristics including the use of temperature measurements from instruments like the Thermal Emission Spectrometer (TES) or Thermal Emission Imaging System (THEMIS) used to study the surface thermophysical properties [1-4]. These studies provide quantitative information on rock abundance and surface slope characteristics and in doing, aid in the selection of future landing sites [1]. Here we investigate the use of a unique and limited dataset from the THEMIS instrument, the Routine Off-nadir Targeted Observations (ROTO), made possible by off-axis rotation of the Mars Odyssey spacecraft. This approach is complementary to that of Bandfield & Edwards [1], however it utilizes this unique THEMIS dataset to examine changes in radiance values due to local slope variation and roughness.

Location: A ROTO image triplet was acquired of the flow field in Daedalia Planum to the southwest of Arsia Mons. This flow field was targeted due to its relatively young age, geologic mapping constrains the flow ages in this region to be ~100 My, and the unusual thermophysical variations between flows [6-8]. Sub-pixel temperature mixing is also present and is suggested to be caused by a rough surface[3]. Based on this, these flows have been proposed to exhibit one of the largest degrees of centimeter to meter scale roughness on the Martian surface due in large part to the flow field's young age [3].

Methods: A ROTO image triplet containing a nadir, 13° off-nadir, and 25° off-nadir viewing angles were acquired of a region south of Arsia Mons (-24° 21' 28.12"N; -122° 37' 47.44"). All ROTOs were acquired within the same week, in the same Mars year, and roughly at the same time of day. Calibrated surface radiance spectra were extracted along two transects: (1) through an impact crater (Figure 1) and (2) across a volcanic flow (Figure 2) to initially examine any possible radiance changes caused by variations in surface roughness and slope. Per-pixel radiance spectra were extracted from points along the transect. These targets were chosen to represent the largest topographic slopes in the ROTO image (Figure 1) and the roughest surfaces (Figure 2) [1,3]. Radiance spectra from points along the transects that show the greatest variation in terrain, slope and roughness, were chosen for study.

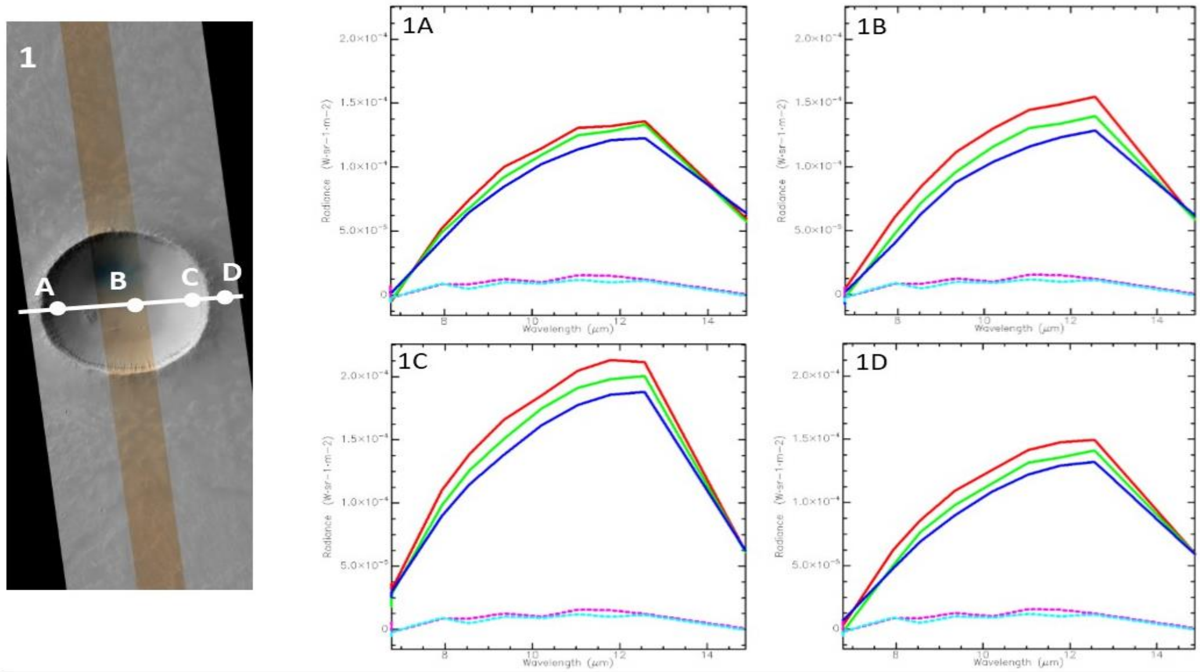
Results: The sunlit slopes of the crater wall (Figure 1C) show the highest overall radiance for all three ROTO observations. Small changes in spectral contrast with viewing angle (~10%) are also observed on both the sunlit (1C) and shaded (1A, 1D) sides of this slope. The shaded slopes (1A, 1D) show the least variation in radiance between the observations. Additionally, small variations in spectral shape are observed in all locations except location 1C, the bright sunlit slope.

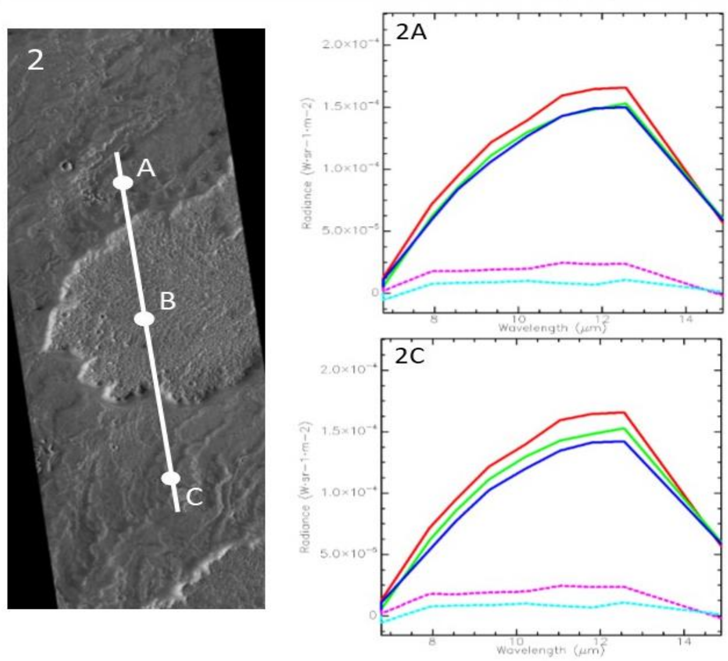
Radiance spectra from two locations on the flow field that appear smoother in HiRISE images and one area that appears rougher were extracted (Figure 2) [8,9]. At all locations along the transect, the -25° off-nadir observation shows the highest spectral radiance. The rough flow surface has the greater change in spectral contrast and spectral shape than the smooth locations. This may be due to sub-pixel temperature mixing caused by shadows in rough terrain [1].

Generally, for both transects the -25° off-nadir data shows the highest spectral radiance followed by the -13° observation. The nadir viewing angle has the lowest.

Discussion: Where viewing a surface from orbit in the TIR, the 100-m orbital spatial resolution does a poor job of representing sub-meter scale surface morphology [1]. Slopes produce differences in surface emission and the subsequent radiance observations due to changes in surface temperature [1]. The observed variation in ROTO-derived radiance values and spectral shape validate this and are likely due to changes in sub-pixel surface roughness.

Further work is needed to quantify the observed spectral variation and link the results to prior modeling studies [3]. The next step of this work will combine ROTO data with the θ-bar surface slope distribution model [10]. We look to investigate whether ROTOs are able to determine precise surface roughness at a sub-pixel scale. If so, the results can be combined with high-resolution digital models to quantify surface morphology with unit age and regional geology. ROTOs are a unique dataset made possible by the mission team and hopefully will be acquired elsewhere on the planet during the next extended mission.





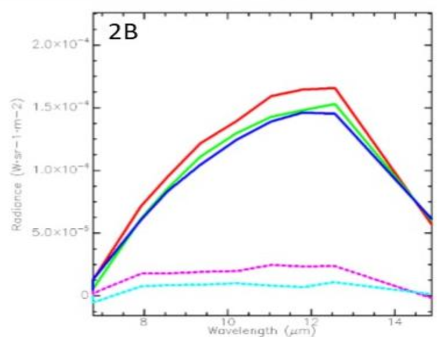


Figure 1. HiRISE image of an impact crater south of Arsia Mons centered at -24° 15' 23.46" N, -122° 35' 44.55" E. **Figures 1A-1D:** Corresponding radiance spectra to transect points. Red corresponds with -25° off-nadir, green with -13° off-nadir , Blue with nadir viewing. Magenta dashed line is -25° off-nadir subtracted from nadir, and cyan dashed line is -13° off-nadir subtracted from nadir.

Figure 2. HIRISE image of a volcanic flow field south of Arsia Mons centered at -24° 43'45.20"N , -122° 41' 27.34"E. **Figures 2A-2C:** Transect radiance spectra follow the same color scheme as figures 1A-1D.

[1] Bandfield J.L. and Edwards C. S. (2008) *Icarus, 193,* 139–157. [2] Simurda C.M. et al (2018), *LPSC XLIX* Abstract # 1792. [3] Bandfield J.L. et al. (2009) *Icarus, 202,* 414-428. [4] Mushkin A. and Gillespie A.R. (2008) *Geo. Phys. Res. Lett., 33,* L18204. [5] Mushkin A. and Gillespie A.R. (2005) *Rem. Sens. Envi., 99,* 75-83. [6] Ramsey M.S. and Crown D.A. (2010) *LPSC XLI,* Abstract # 1111. [7] Ramsey M.S. and Crown D.A (2017) *JVGR, 342,* 13-28. [8] Crown D.A. et al (2015) *LPSC XLVI,* Abstract # 1439. [9] Crown D.A. et al (2010) *LPSC XLI,* Abstract # 2225. [10] Hapke B. (1984) *Icarus, 59,* 41-59.